Biological characterisation of the Orange-Fish River Basin, Namibia

John Irish
November 2008

About the Author

John Irish grew up in Namibia, with an interest in all aspects of the Namibian environment. His formal tertiary training is in Entomology, and he holds a PhD from the University of Pretoria. He has worked for the National Museum of Namibia, the National Botanical Research Institute, the National Biodiversity Programme and the Gobabeb Training and Research Centre, besides freelancing as a consultant. He is interested in biogeography and ecology, and in the development of bio-informatics tools as an aid to sustainable environmental utilisation.

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This series of reports presents findings from research carried out in the Ephemeral River Basins Project – ERB. The project, implemented in three ephemeral river basins in southern Africa – one each in Namibia, Botswana and South Africa – is funded by the Norwegian Ministry of Foreign Affairs through the Royal Norwegian Embassy in Pretoria.

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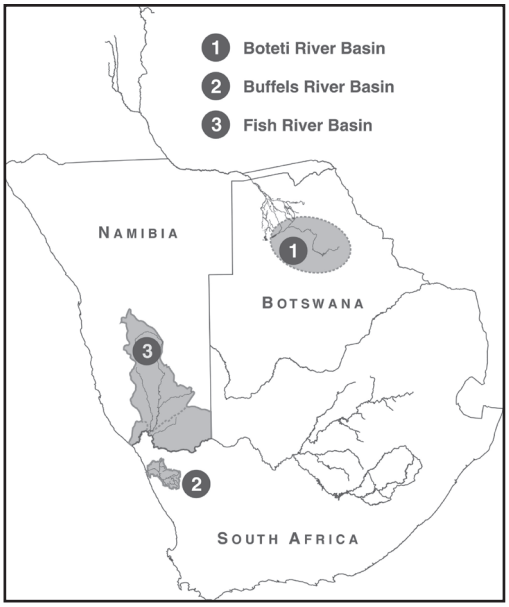
Ephemeral River Basins in Southern Africa Project

Ephemeral River Basins (ERB) in Southern Africa is a project that promotes the sustainable, equitable and improved utilisation of water and other natural resources in ephemeral river basins in southern Africa through the process of integrated resource management (IWRM). Although IWRM is accepted – internationally and regionally – as the approach promoting sustainable management of water resources and the river basin is considered the ideal unit over which to apply it, the basin management approach has not been widely tested and implemented in ephemeral river basins in southern Africa.

The ERB in Southern Africa Project, however, explores the potential and options for basin management in three ephemeral river basins in southern Africa – the Boteti, an outflow of the Okavango Delta, in Botswana, the Buffels, a westward-flowing ephemeral river in the Northern Cape, in South Africa and the Fish River Basin, a tributary of the Orange River, in Namibia.



Despite being ephemeral, all three river basins are essential water resources in their areas. The three basins have different biophysical and socio-economic characteristics and are managed under different legislative, policy and institutional arrangements. Together, they thus provide good examples to explore the potential and options for basin management in ephemeral rivers and on which to base a comparative analysis for wider application.

The purpose of the project is met by five main activities:

- Sensitising managers and users of natural resources to the concepts of IWRM and basin management
- Assessing the potential for the application of integrated basin management
- Establishing appropriate forums for promoting IWRM in the three basins
- Documenting the biophysical and socio-economic status of the three basins
- Documenting best practices, lessons learnt and case studies as a comparative analysis for wider application.

This is one of many reports emanating from the ERB in Southern Africa Project. For more information on the project, visit our website at http://www.drfn.org.na/erb/index.html

The project is funded by the Norwegian Ministry of Foreign Affairs and co-ordinated by the Desert Research Foundation of Namibia (DRFN). Work in the Boteti River Basin is being led by the Harry Oppenheimer Okavango Research Centre (HOORC), in the Buffels by the Surplus People Project (SPP) and in the Fish by the DRFN.

Glossary

adiabatic	changes in temperature, pressure and volume in a parcel of air
chamaephytic	plants that bear buds close to the ground; also known as dwarf-shrubs
edaphic	relating to the physical or chemical conditions of the soil
hemicryptophytic	plants with shoots at ground level, typically herbaceous perennials, such as grasses
lignicolous	wood-eating
phanerophytic	projecting into the air as stems, normally woody perennials, such as trees and large shrubs
psammophilous	sand-loving; plants that grow in, or animals closely associated with, loose soil or sand
refugia	habitats that have remained unaltered by a climatic change affecting surrounding regions and forms a haven for relict species
therophyte	plants that complete their lifecycles rapidly when conditions are favourable, but otherwise survive unfavourable seasons as seeds or other resting forms
topography	variation in a relief of a landscape

Abbreviations and acronyms

CITES	Convention on International Trade in Endangered Species
GBIF	Global Biodiversity Information Facility
IUCN	International Union for the Conservation of Nature
NaBiD	Namibia Biodiversity Database
OFRB	Orange-Fish River Basin, Namibia
pers. comm.	personal communication
pers. obs.	personal observation
QDS	quarter-degree square
spp.	species (pl.)
WIND	National Herbarium of Namibia

Contents

Orange-Fish River Basin, Namibia

1. Biogeographical patterns in the Orange-Fish River Basin, Namibia

Biogeography is the study of spatial patterns in the occurrence, distribution and abundance of species, and the reasons for the existence of such patterns. Knowing where a particular species occurs, and why it occurs there, are fundamental prerequisites to managing that species. In the context of global climate change, knowledge of biogeography becomes important as a tool to predict potential future changes in species distribution and to pro-actively adapt species management strategies.

Biogeographical patterns come at different scales. From large to small, the ones most relevant to Namibia are respectively biomes, biome modifiers, superimposed systems, and refugia (Irish in prep.).

1.1 Biomes

Biomes are large areas that are primarily defined by their dominant plant life forms. Secondarily, biomes are defined by the distinctive climatic regime that results in their particular type of plant dominance. At the tertiary level, biomes can be defined by a distinctive suite of animal life associated with the distinctive plant life forms, the distinctive climate, or both. Four different biomes are found in Namibia (Irish 1994), and all four are represented in the Orange-Fish River Basin in Namibia (OFRB) (Figure 1).

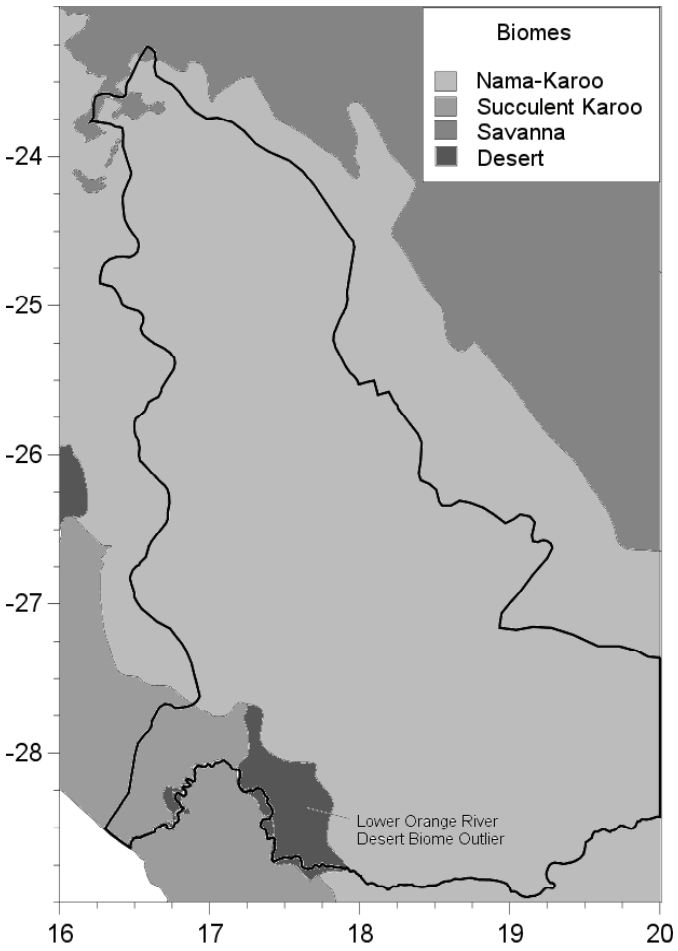


Figure 1: Biomes represented in the Orange-Fish River Basin

1.1.1 The Nama-Karoo Biome

The major part of the OFRB, with the exception of the far north and the south-west, falls within the Nama-Karoo Biome (Figure 1). Vegetatively, the Nama-Karoo is characterised by chamaephytic-hemicryptophytic co-dominance, i.e. shrubs and grasses make up most of the perennial plant life; trees are absent except along watercourses, and forbs only appear after rain. Climatically, the Nama-Karoo is characterised by relatively low summer rainfall (average 50-230 mm per year). Year to year variability of rainfall is very high in the south and west, where years without significant rainfall are normal, but become less so towards the north and east. Because of this unpredictability, both plants and animals are adapted to spending large parts of their lifecycles in dormant states (eggs, pupae, seeds, bulbs) in order to survive extended dry periods. They hatch or sprout after rain, or opportunistically disperse into the area from the adjacent Savanna Biome. Food chains tend to be short and simple. Rock mimics are a special feature of the invertebrate fauna. The Nama-Karoo Biome extends southwards beyond the borders of the OFRB into South Africa, and northwards as a narrow strip into Angola.

1.1.2 The Succulent Karoo Biome

The southwestern part of the OFRB, along the Orange River from the escarpment to the sea, falls within the Succulent Karoo Biome (Figure 1). Vegetatively, the Succulent Karoo is characterised by almost absolute chamaephytic dominance, i.e. almost all plant life consists of shrubs. Trees are absent except along watercourses, while grasses and forbs are scarce. Climatically, the Succulent Karoo is characterised by low winter rainfall (average 40-90 mm per year). The amount of rainfall may vary from year to year, but rainfall *per se* is very dependable and years without rainfall are not normal. Because rain falls in the colder half of the year, the effect of evapo-transpiration is reduced and plants and animals can thrive at rainfall levels that would be too low to support similar populations where the rain falls in summer. For this reason, the Succulent Karoo is not merely 'Nama-Karoo with winter rainfall', but represents an entirely different habitat with entirely different biota. Plant life is characterised by spectacular flower displays, and invertebrate guilds include a high proportion of specialist flower and pollen-feeders. The Succulent Karoo extends northwards beyond the borders of the OFRB as far as Aus, and southwards into South Africa. The Namibian Succulent Karoo represents the most arid part of the entire biome.

1.1.3 The Savanna Biome

A very minor part of the far northern OFRB, mainly representing the summits of the Remhoogte and Rantberge, falls within the Savanna Biome (Figure 1). Vegetatively, the Savanna Biome is characterised by phanerophytic-hemicryptophytic co-dominance, i.e., trees and grasses make up most of the plant life; shrubs are present but in lesser numbers, and forbs mostly appear after rain only. Climatically, the Savanna Biome is characterised by relatively high summer rainfall (average 170-700 mm per year, although those parts within the OFRB are at the lower end of this scale). Year to year variability in rainfall is less extreme than in the Nama-Karoo, and years without any rainfall are not normal. Some plants such as *Albizia* or *Acacia* spp. flower annually in spring in response to increasing day length in the absence of rainfall, demonstrating that in the Savanna, lifecycles are not as absolutely dictated by rainfall as they are in the Nama-Karoo. The presence of trees results in a landscape with a wider variety of niches and hence higher levels of biodiversity. A characteristic feature of invertebrate life is the presence of lignicolous (wood-eating) taxa that are less common in other Namibian biomes.

1.1.4 The Desert Biome

The Namib Desert proper falls outside the OFRB, but parts of the Lower Orange River Valley are assigned to an isolated outlier of the Desert Biome (Figure 1). Vegetatively, the Desert Biome is characterised by therophytic dominance, i.e. permanent plants are few and far between, and the dominant life forms are ephemeral and only appear after rain. Climatically, the Desert Biome is characterised by very low rainfall (average less than 40 mm per year). Rain can fall at any time of the year (though statistically it is more likely in summer), and years without any rainfall are normal. Plant and animal life can be divided into a few highly-adapted perennial species that survive with minimal moisture and a larger number that are normally inactive except after rare rainfall events. The Lower Orange River Desert Biome Outlier is almost entirely contained within the borders of the OFRB. It is widely separate from the main Namib Desert Biome, and ecologically quite different. Being so far inland, sea fog is not important as a source of moisture. It lacks sand dunes and the distinctive psammophilous fauna of the Central Namib. We actually know very little about the biodiversity and ecological processes of this Desert Outlier.

1.2 Biome modifiers

Within the borders of any primary biome, topographical and edaphic factors may ameliorate or exacerbate the underlying causal climatic factors (in Namibia this is usually the availability of moisture) to result in recognisable subregions within the biome.

1.2.1 Topographical biome modifiers

Topography (variation in relief) causes landscape diversity, which in turn results in habitat diversity. Average temperature decreases with altitude. While the summits of mountains in the OFRB may not necessarily receive more rainfall than the surroundings, any that does fall will last longer and have more biological effect because of the slightly cooler conditions at altitude. In addition, because of the tilt of the earth's axis, in the southern hemisphere, north-facing slopes tend to be hotter and drier than south-facing slopes. The complex interplay between altitude, aspect and base climate, results in a habitat mosaic in mountains that presents a wider variety of niches and harbours higher biodiversity than the surrounding flatlands. Within the OFRB, the relatively higher biodiversity along the southern escarpment at Brukkaros and in the Karas and Huns mountains, are examples of this phenomenon.

Conversely, deep valleys may lie in the rain shadow of surrounding higher ground, making them drier. In addition, they tend to trap adiabatic heat, making them hotter as well. Depending on their orientation, this effect may be exacerbated (east-west valleys are essentially in the sun all day long) or partly ameliorated (opposite sides of north-south valleys are in the shade for part of the day). The main Lower Orange Desert Outlier is situated in the rain shadow of the Richtersveld Mountains that tap rain-bearing winter cold fronts that come from the south-west. The valley is also very deep and is orientated east-west. All these factors combine to exacerbate the inherently low rainfall of the area and reinforce the existence of a Desert Biome Outlier. Further west, a smaller desert patch is situated in the rain shadow north-east of the Schakal Mountains (Figure 1), and similar patterns can be seen repeated on a less noticeable scale in deep valleys throughout the OFRB. By way of contrast, the Lower Fish River Canyon, because it is orientated north-south and the canyon sides afford the valley shade for part of the day, is decidedly part of the Nama-Karoo, and not the Desert Biome.

1.2.2 Edaphic biome modifiers

Edaphic factors (soil or substrate) can also modify the underlying biome. Sandy substrates are a major biome modifier in Namibia. Sand is highly permeable, so that rainfall penetrates deeply and moisture is retained, while less permeable soils tend to lose the benefit of rainfall more quickly due to evaporation closer to the surface. Other factors being equal, sand tends to bump the vegetation to a higher level than is normally possible under the climatic regime. As an example: the Kalahari dunes to the east of the OFRB tend to have vegetation that is classified as savanna, even though they are situated in an area with a climate that can only support Nama-Karoo vegetation in the absence of sand. On a smaller scale, sandy substrates throughout the OFRB support different biota than would otherwise have been the case.

While sand improves moisture retention, calcrete hardpans exacerbate the already poor permeability of calcerous soils through shallow impervious layers that not only prevent rainfall from penetrating deeply, but also restrict the roots of most plants to the dry layer of soil above them. In the OFRB, calcrete hardpan is especially prevalent on the Kalk Plateau, resulting in the characteristic stunted vegetation of the area, and the multitude of small pans that dot the landscape.

1.3 Cross-cutting habitats

Some habitats are determined by factors that are independent of climate, hence they tend to cut across biome boundaries.

Ephemeral watercourses are the most prominent cross-cutting habitat in the OFRB. Through access to higher groundwater levels than the surroundings, they support more vegetation, typically trees, in the otherwise treeless Nama-Karoo biome. This allows tree-loving herbivorous taxa to extend into areas that would otherwise be unsuitable for them, followed by their predators, parasites, commensals, etc., besides similar suites of taxa that are based on dead wood, pods or roots, instead of leaves.

Dunes are another cross-cutting habitat. Scattered small dune fields (generally <1 km^2) occur throughout the OFRB (Poller 2005). They are too small to act as edaphic biome modifiers, but they do harbour distinctive suites of psammophilous plants and animals that differ from those in the surroundings.

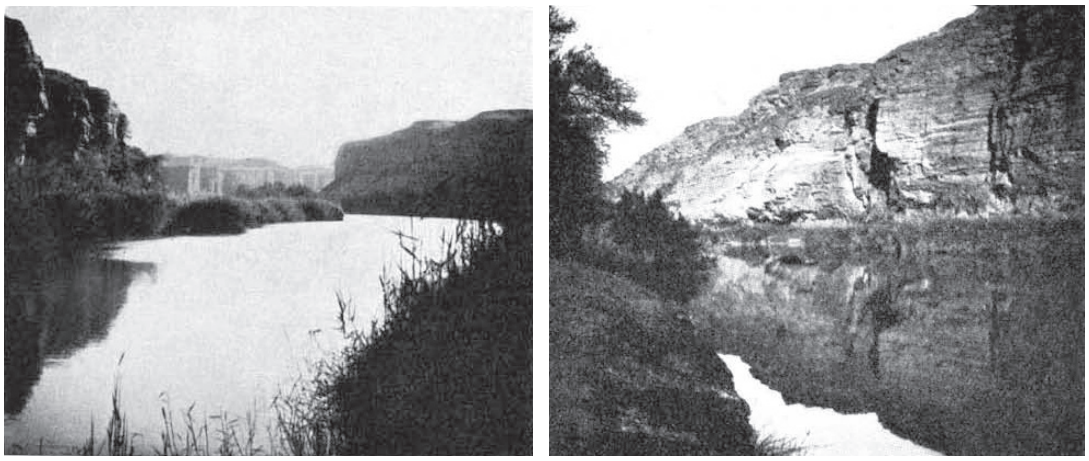


Figure 2: Fish River near Seeheim in 1911 (from Michaelsen, 1914)

Aquatic habitats can also occur in any biome. The Orange River is an example of an aquatic habitat cutting across biome boundaries in the OFRB. The Fish River was formerly a much wetter river than today, as already evidenced by its name, which

goes back as far as there are records. Michaelsen (1914) visited Namibia in 1911 and encountered perennial water in the Fish River on a scale that is unrecognisable today (Figure 2). Could the construction of the Hardap Dam have led to the subsequent desiccation of the river, or is there another reason?

1.4 Refugia

Once the spatial distributions of most species have been explained with reference to biogeography as determined by climate, biomes, topography, edaphic factors and cross-cutting habitats, a few unexplained anomalies will always remain, and they can often be explained by palaeo-historical factors. There have been climate changes in past earth history, and often these have left so-called 'relict species' isolated in small pockets of habitat that still resemble the original more widespread environment they used to live in. Such relict habitat pockets are called 'refugia'. Mountaintops are classical refugia, for the same reasons that they act as topographical biome modifiers. Centrally in the OFRB, Brukkaros Mountain is a refugium that harbours many plants that are more typical of winter rainfall areas (Burke 2003), while on the edge of the OFRB the fountains in the Naukluft Mountains are refugia harbouring aquatic invertebrates that otherwise occur only outside Namibia (e.g. Endrödy-Younga 1993, Perkins and Balfour-Browne 1994). The grey rhebuck (see below) is also a relict species.

2 Species of the OFRB

No comprehensive species listing for the OFRB exists, and information presented here was gleaned from a variety of available datasets. Some had spatial information based on point coordinates, but others were based on quarter-degree squares (QDS). This necessitated decimating point coordinates into QDS references in order to make the different datasets comparable.

A quarter-degree square is an area with all four sides 15 geographical minutes (about 50 km at Namibian latitudes) in length. The OFRB includes 203 QDSs that fall completely or largely within its borders. The databases used to derive the species list follow.

2.1 Tree Atlas of Namibia

The database, which formed the basis of the *Tree Atlas of Namibia* (Curtis and Mannheimer 2005) was used. Spatial information is QDS based. As explained above, most of the OFRB is not really tree country. An initial search turned up only 8,349 records from the OFRB. Some were multiple records of the same species from the same QDS by different atlassers at different times. When aggregated, 3,803 unique records of 155 tree species from 191 QDSs remained.

2.2 Avian Database

The Namibian Avian Database was produced in 2000 as part of the Southern African Bird Atlas Project, and is currently available on-line at http://www.biodiversity.org.na/birds/ birdhome.php. Spatial information is QDS based. A search resulted in 10,668 records of 365 species from 192 QDSs within the OFRB.

2.3 National Herbarium Database

The National Botanical Research Institute kindly serviced an information request for plant records from the collection database of the National Herbarium of Namibia (WIND). Spatial information is QDS based. An initial search produced 12,392 records from the OFRB. However, some were identified to generic level only, and there was

some duplication due to repeat collections by different botanists at the same locality. After factoring these out, 11,713 records of 1,926 plant species from 199 QDSs remained.

2.4 Namibia Biodiversity Database (NaBiD)

NaBiD includes mainly published literature records, and is particularly useful as a source of invertebrate information, but covers all taxa. Spatial information is coordinate-based, but was decimated to QDSs for the purposes of the present study. An initial search turned up 2,386 records from the OFRB. A small number were records of fossils, and some from the Oranjemund area were representative of marine taxa from the same QDS as the westernmost parts of the OFRB. These were excluded, since they contribute little to an understanding of OFRB biodiversity. A number of duplicate records at the QDS level were also excluded, ending up with 2,329 records of 874 species from 165 QDSs.

2.5 Global Biodiversity Information Facility (GBIF)

GBIF data is mainly specimen-based from museum collections and is available at http://www.gbif.org. It currently (October 2008) hosts an impressive 147 million records worldwide, of which 224,011 are from Namibia. However, only 17,642 of the latter are geo-referenced (i.e. potentially useful for a study of the OFRB).

In the present case, a search turned up 6,840 purported records from the OFRB. The dataset was then refined by removing obvious mistakes. These included:

- Records from localities outside Namibia (South Africa, North America, northeast Atlantic Ocean, Cape Verde Islands), despite being listed with coordinates that are within the OFRB
- Records from Namibia but outside the OFRB (Otjiwarongo District, Lüderitz), despite being listed with coordinates within the OFRB
- Marine fish taxa without localities, but with coordinates that place them in the interior of southern Namibia (extant fish, not fossils)
- Records that are identified to higher levels (genus, family, order) only, and hence unusable in this species-based study
- In the case of groups that are well-known in Namibia (e.g. reptiles), Namibian records of species that definitely do not occur here
- *Nomina nuda* – species identified with names that do not exist elsewhere in taxonomical literature.

Some more, possibly perfectly accurate records were also removed simply because they were incompatible with this study's objectives:

- Fossil taxa
- Marine taxa
- Mammal collection data from five foreign museums that are independently part of NaBiD and had already been included above
- Normal duplicate records.

What remained were 192 records of 92 species from 65 QDSs. GBIF is a potentially very valuable resource, but it currently indiscriminately serves whatever contributing museums offer, and this results in GIGO (Garbage In, Garbage Out). It is especially disheartening to see that some foreign museums that had their Namibian records georeferenced or corrected by NaBiD almost two years ago, are still serving the original, erroneous data to GBIF.

2.6 Additional sources

Inspection of the species lists resulting from the previous data mining showed a number of obvious gaps, and they were filled by manually adding species from relevant literature sources. This made the list more comprehensive, but since only species and not localities were added, it made no difference to the spatial biodiversity analysis and mapping.

Additional sources utilised were:
- Bethune and Roberts (1991) for freshwater fish
- Griffin and Channing (1991) and Channing and Griffin (1993) for amphibians
- Griffin (2002) for reptiles
- Griffin and Coetzee (2006) for mammals.

In all, the databases produced 28,705 records of 2,960 species from all 203 QDSs in the OFRB, while literature sources added another 112 species.

A list of all recorded species follows in Appendix 1. Figure 3 shows the number and proportion of species in each major group of organisms. Comparison of the graphs for the OFRB and the whole of Namibia indicates that plants and birds were overrepresented in the datasets used, and invertebrates were underrepresented. This is a fair reflection of the data bias inherent in the unequal representation of different groups in available data sources, and is a reality of Namibian bio-informatics.

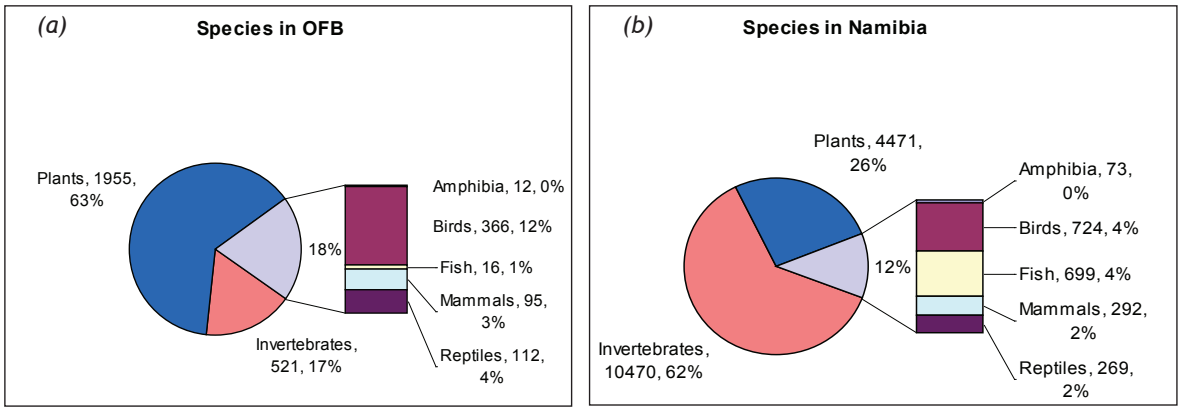


Figure 3: Comparison of number of species in each major group of organisms, as represented in the OFRB (a), with their total number of species known from Namibia (b).

3 Biodiversity patterns in the OFRB

It follows from the biogeographical characterisation of the OFRB given above that biodiversity will vary across the OFRB, both in the number of species that occur in each area, and in the species composition that makes up that number. The number of species recorded from each QDS would represent a measure of relative biodiversity, ***if*** collecting/recording density for all species across all QDSs were uniform. It is definitely ***not*** uniform, and the challenge becomes to tease out the underlying biodiversity patterns from the more obvious collecting intensity patterns.

Experience has shown that Namibian biodiversity records are concentrated around major towns and along major roads, as the output from a point-based dataset shows (Figure 4). When one compares that with a plot of species per QDS (Figure 5), major roads like Keetmanshoop-Mariental, Mariental-Kalkrand, Mariental-Maltahöhe, Maltahöhe-Aus,

Keetmanshoop-Aus, Helmeringhausen-Goageb and Karasburg-Nakop can be recognised by linear successive QDSs with higher numbers of species than the surroundings.

Towns may also be identified. The QDSs containing both Keetmanshoop and Mariental have very high numbers of species recorded, despite experience showing that the immediate vicinity of both towns is not particularly more biodiverse than surrounding areas. Other towns like Maltahöhe, Gibeon, Helmeringhausen or Oranjemund are similarly noticeable on Figure 4.

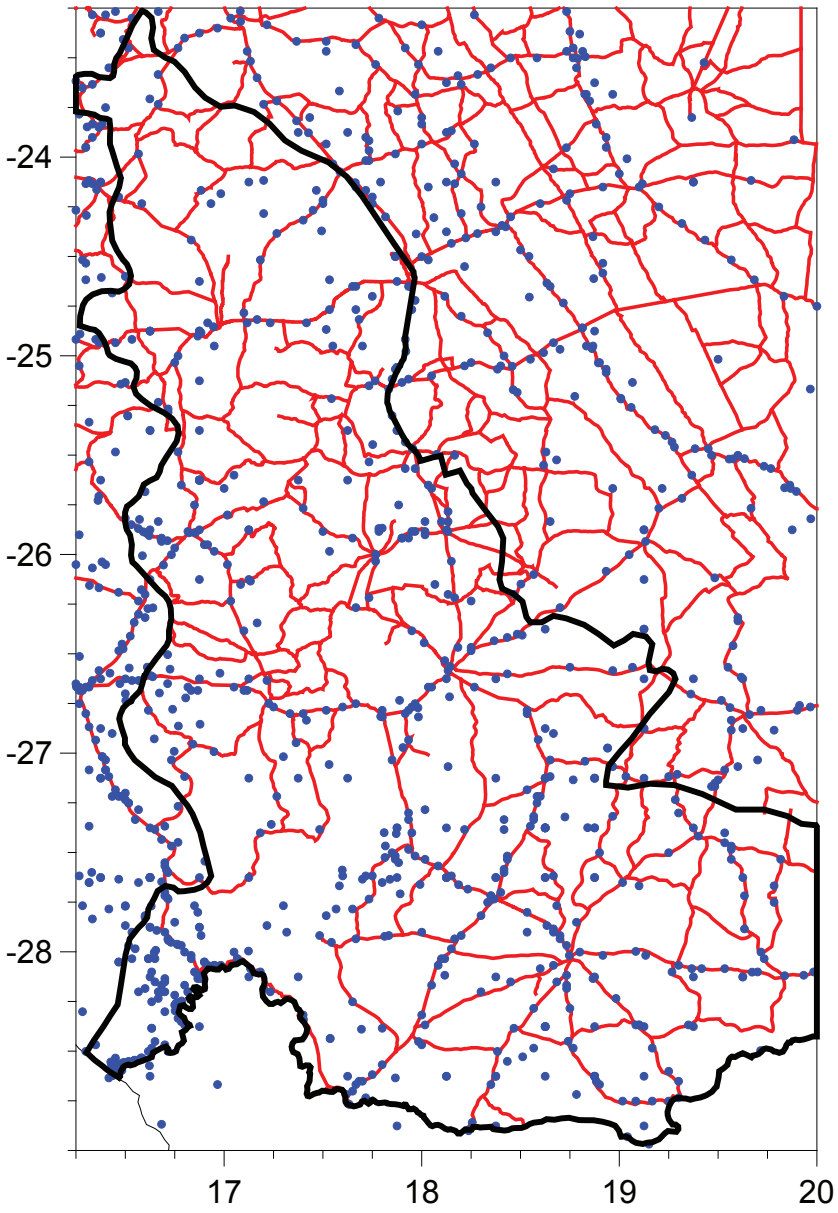


Figure 4: Positive correlation of collecting localities (blue dots) with major roads (red lines) in the OFRB
Data source: NaBiD

The remaining areas of high species numbers that are not associated with major towns or roads probably represent areas of inherently higher biodiversity. From north to south (Figure 5), they are:

- *The Naukluft Mountains*. Though some of the high numbers here are possibly associated with roads, the highest number of 561 is from QDS 2416Ab that includes Naukluft campsite (actually just outside the OFRB). It probably represents truly high biodiversity.

- *Southern escarpment*. While some of the relatively high species numbers along the western border of the OFRB may be ascribed to major roads, the case of QDS 2517Da, with 170 species but no major roads, indicates that there is some inherently higher biodiversity along the escarpment west of Helmeringhausen.
- *Brukkaros Mountain*. QDS 2517Dd with 234 species includes the town of Berseba, but the species number is so much higher than the surroundings that it is believed to represent inherently high biodiversity associated with Brukkaros, rather than a 'town effect'.
- *Karas Mountains*. QDS 2618Dd with 203 species has no major roads and indicates that the cluster of high species numbers centered on the Karas Mountains probably represents inherently higher biodiversity.
- *Rosh Pinah/Obib*. QDS 2716Dd with 585 species is the highest recorded here. Some of this may be Rosh Pinah town/road related, but the case of nearby QDS 2816Ba with 407 species but no major roads, shows that the area has inherently high biodiversity.
- *Fish River Canyon area*. While QDS 2717Cd with 357 species includes Ai-Ais and may partly be a 'town effect', other high numbers nearby, e.g. QDS 2717Cb with 232 species but no major roads, indicates that some of this may be inherently high biodiversity.
- *Warmbad area*. While some of the cluster of higher numbers in the southeast may be road-related, QDS 2819Cc with 160 species but no major roads indicates that some of this may be inherently high biodiversity.

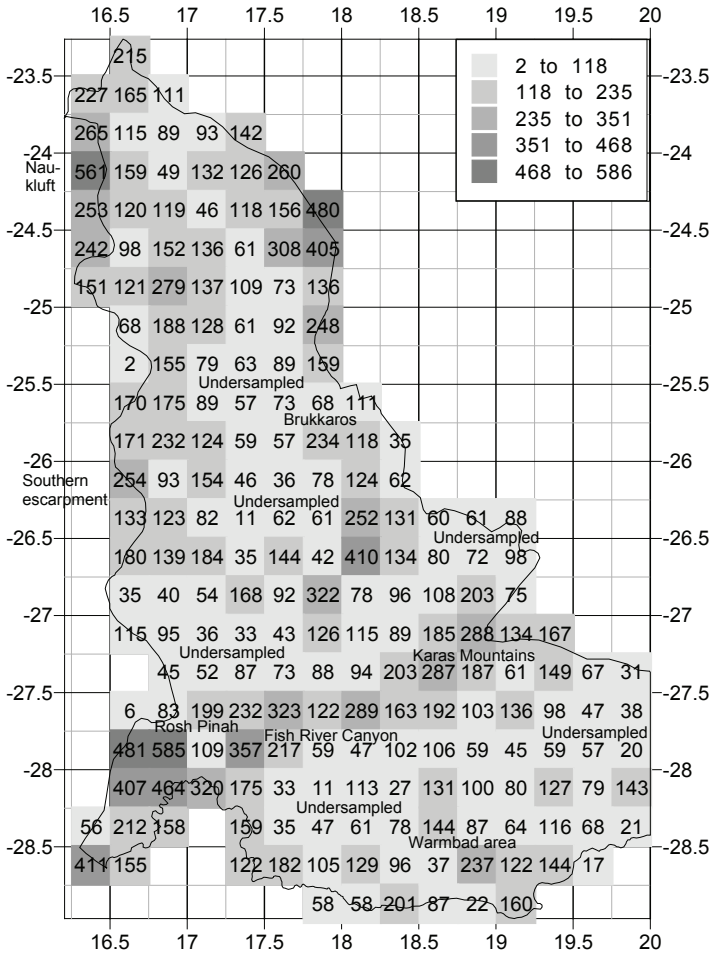


Figure 5: Number of species recorded per quarter degree square in the OFRB, areas of apparent higher biodiversity marked, as well as areas of apparent low biodiversity that can probably be attributed to undersampling.

As a converse of the previous exercise, the following areas have unusually lower biodiversity than their surroundings (Figure 5). This is probably due to low sampling intensity, rather than inherently low biodiversity:

- A large area in the *central OFRB*, enclosed by the Keetmanshoop–Mariental–Maltahöhe–Bethanie–Goageb–Seeheim roads, and centered on the communal areas of Namaland, reaching a low of only 11 recorded species in QDS 2617Ac
- The *Huib Plateau* and the adjacent *Lower Konkiep Valley*, reaching a low of 33 species on QDS 2717Ab
- The south-east. The few QDSs with high species numbers here are exceptions in a wide area with generally low recorded numbers, e.g. QDS 2817Bb with 11 and QDS 2719Dd with 20 species respectively. The mix of a few high and many lower numbers in a relatively homogenous area reinforces the view that the low numbers are due to undersampling.

4 Endemism patterns in the OFRB

Endemic Namibian species are those that are only found within the borders of Namibia and nowhere else in the world. They are a special component of biodiversity since they are both a unique national heritage and an exclusive national responsibility. Where near-endemic species range across national borders, the usual practice is to consider a species endemic to a particular country when more than 75% of its distribution range falls within that country, and this convention was also followed here.

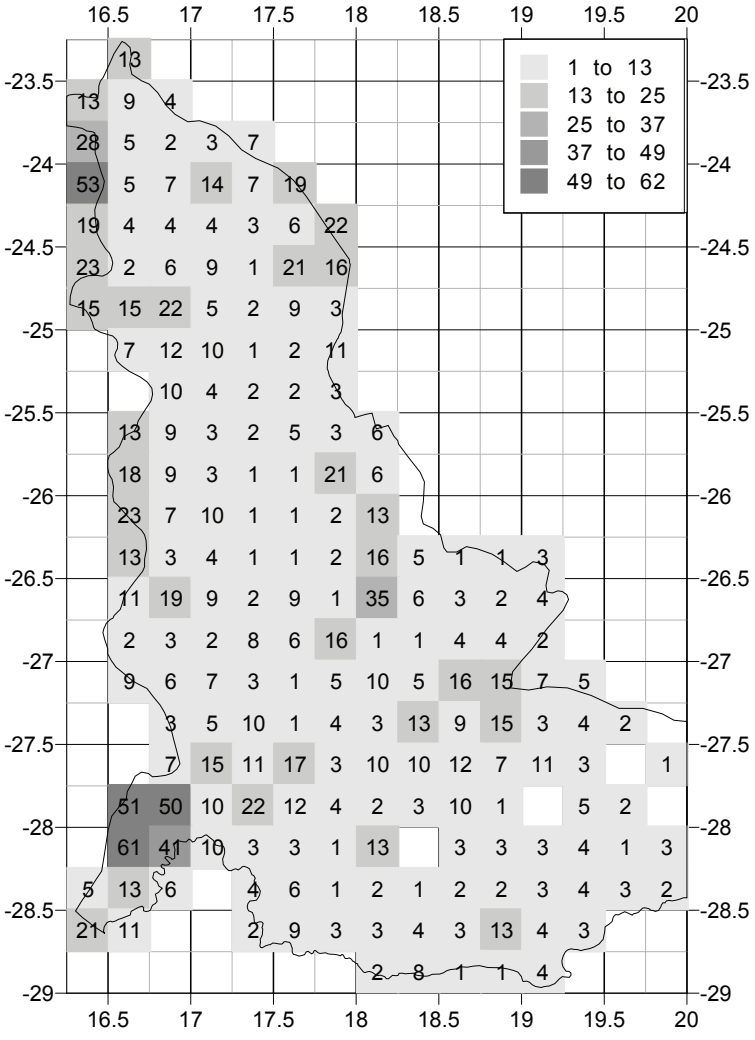


Figure 6: Total number of endemic species per QDS in the OFRB

The unequal sampling intensity across the area made quantification of endemicity difficult. If one simply looks at numbers of endemic species, a pattern emerges (Figure 6). There are two areas with high numbers of endemic species: the Rosh Pinah/Obib area, and the Naukluft. These areas do have many endemic species, but comparison with Figure 5 shows that they are also some of the better-sampled areas in the OFRB. Keetmanshoop, another well-sampled area that is not known for higher than usual rates of endemism, is also visible on Figure 5. The implication is that raw numbers of endemic species are not a good measure of endemicity: the more species that are recorded from a QDS, the more endemics will obviously also be recorded.

A more accurate measure of endemicity might be the proportion of species recorded from each QDS that are endemic (Figure 7). There is one snag with this though: some QDSs that have very few species to begin with, end up having very high endemicity rates, simply by virtue of fortuitously having one or two endemic species. In order to prevent these false positives, undersampled QDSs (the lower 20% on Figure 5) were *a priori* excluded from the calculations for Figure 7.

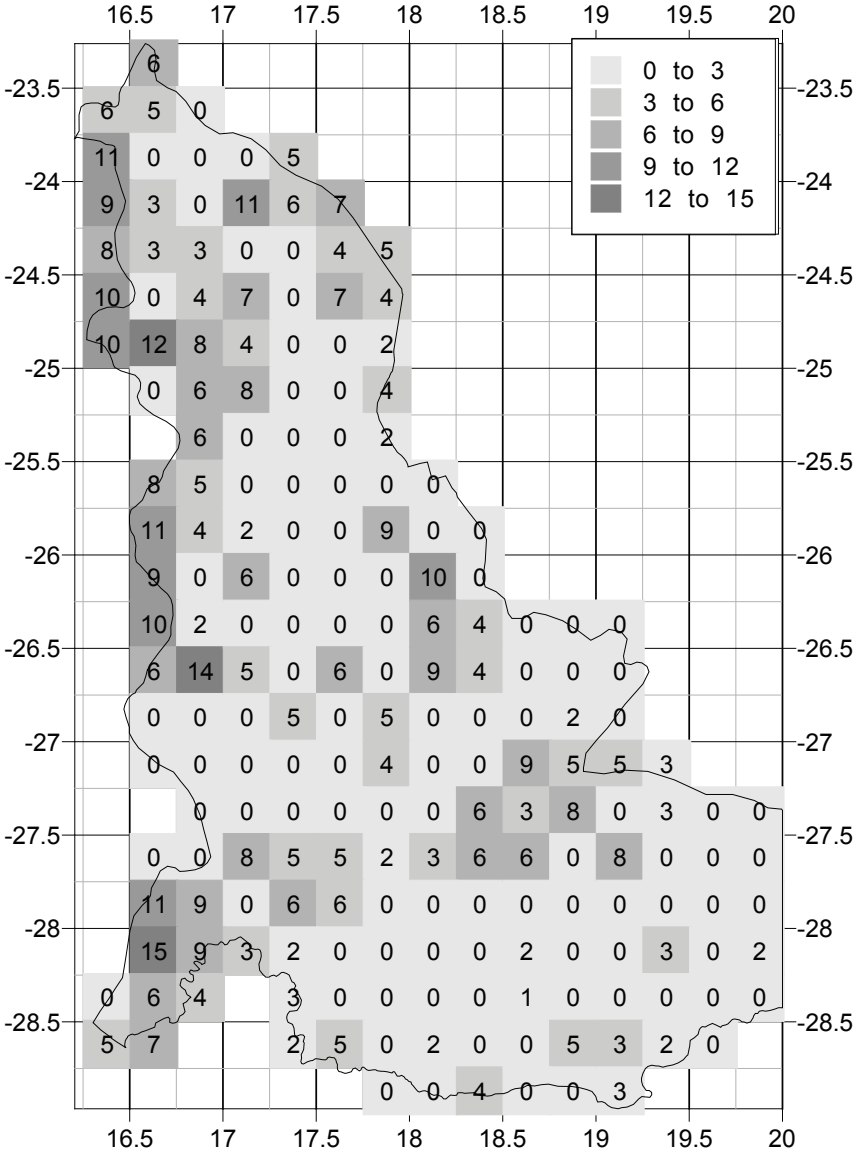


Figure 7: Endemic species as a percentage of the total number of species recorded from that QDS, excluding undersampled QDSs.

What emerges is that the escarpment along the western edge of the OFRB has the highest endemism rates for the entire area. The gap in the western strip of high endemism around 27°S corresponds to an undersampled area (Figure 5). This area should be a target for future inventorying. In the south, the western area of higher endemism widens beyond the escarpment to include the Huns Mountains and the Fish River Canyon area. The escarpment (generally) is known for high endemism rates. A second cluster of higher endemism is centered on the Karas Mountains, also known for high endemism.

A third cluster includes Keetmanshoop and the area north of it as far as Brukkaros Mountain. While the mountain is recognised as a centre of endemism, the rest of this area is not. Similarly the area from Mariental north-westwards is not usually recognised as an endemism hotspot either. The latter two areas may benefit from a more detailed analysis to determine whether they are really centres of endemism, or these are merely spurious effects caused by high sampling rates near two major towns.

Considering the source of this endemism, the majority of the recorded endemics are plants, followed by invertebrates (Figure 8). There are very few endemic vertebrates in the OFRB. However, plants were shown to be overrepresented in the dataset, and proportional endemism was shown to be a truer reflection of endemicity in areas of unequal sampling. If one considers the number of endemic species in each group as a proportion of the total number for that group in the OFRB (Figure 8), invertebrates and reptiles emerge as those with the highest endemism rates in the OFRB.

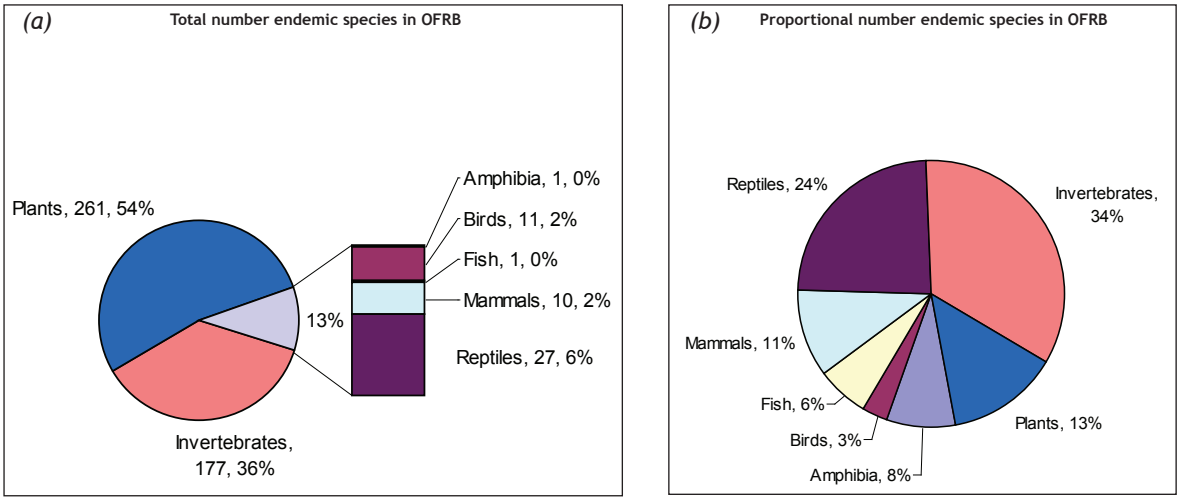


Figure 8: Number of endemic species in each major group of organisms in the OFRB, both as absolute numbers (a) and as a proportion of the total number of species recorded for that group from the OFRB (b).

5 Land management and land-use issues

Biomes are a suitable level at which to look at high-level land management and land-use issues.

The savanna is the only biome in Namibia where crop farming is feasible, but the part included in the OFRB is too mountainous for this. Large-stock farming is appropriate for savanna, but if the area has significant game populations and/or magnificent scenery (as the OFRB Savanna has), eco-tourism would be more environmentally friendly, more sustainable and ultimately more profitable.

In the Nama-Karoo, crop farming is not possible except under irrigation. Areas under irrigation include those at Hardap, Naute and various places along the Orange River; more are, however, planned with the Neckartal Dam development. Large-stock farming is practised in the Nama-Karoo for shortsighted economic reasons, but should be discouraged since it is ultimately not sustainable and causes long-term damage through overgrazing. Small-stock farming is feasible in the Nama-Karoo, but there has tended to be overstocking in the past, with resultant drops in carrying capacity. Much of the Nama-Karoo is not visually appealing from a tourist viewpoint, but the few areas that are (mountains and canyons) could be profitably developed for eco-tourism. The tourism potential of the Nama-Karoo, especially the communal areas, has not been fully realised. It would be in the own best interests of communities to conserve the precious few scenic and biodiverse areas and develop these for tourism, while reserving less scenic areas for small-stock farming, but at sustainable stocking rates. Sadly, attempts at tourism development in unscenic areas are probably doomed to failure.

The Namibian Succulent Karoo is the driest part of the entire biome and unsuitable for any agricultural activity, but highly suitable for eco-tourism, or as conservation or wilderness areas. Most of the Succulent Karoo within the OFRB falls within the /Ai-/Ais Park, or the Sperrgebiet National Park, while the area also includes the Orange River mouth RAMSAR site. The Succulent Karoo in general, and the Sperrgebiet in particular, are global hotspots of plant endemicity.

The desert outliers in the OFRB are similarly unsuitable for agricultural activity, excepting crop farming under irrigation as practiced along the Orange River. The eco-tourism potential of the area is underdeveloped considering the scenic beauty. Given the proximity of the /Ai-/Ais Richtersveld Transfrontier Park, and the highly successful Gondwana Park, there are clear opportunities.

In general, eco-tourism seems to be the first choice for long-term, sustainable and profitable land-use in most of the OFRB, provided the area is scenically attractive. Subsistence, small-stock farming is a viable option in less scenically attractive areas, provided sustainable stocking rates are maintained.

From a biodiversity conservation perspective, it would be ideal to have at least one large-scale nature reserve or conservancy in each biome, preferably also covering a selection of significant biome modified areas. As indicated in Figure 9, conservation coverage in the OFRB can be evaluated as follows:

- *Savanna*: The biome is well covered by conservation areas outside the OFRB. In addition, the Naukluft portion of the Namib-Naukluft Park conserves a patch of mountaintop savanna outlier similar to those in the OFRB.
- *Succulent Karoo*: Most of the biome is already included in the Sperrgebiet National Park and the Huns part of the /Ai-/Ais Park.
- *Desert*: Part of the desert outlier in the southern OFRB is included in the /Ai-/Ais Park. Part of the Aussenkehr property is run as an unofficial nature reserve and this should be developed to give it a more formal status.
- *Nama-Karoo*: The Nama-Karoo is not particularly well preserved. The Hardap and Naute Nature Reserves are margins around dams, limited in extent, artificial and atypical for the biome. The /Ai-/Ais Park and adjacent Gondwana Park do include Nama-Karoo, but are also less typical, being situated at the biome margin. However, they are representative of an area of extensive topographical biome modification. The emergent //Gamaseb and !Khob!Naub communal conservancies cover large

areas, and hold the key to more comprehensive future conservation coverage of the Nama-Karoo.

- *Specific areas of known higher biodiversity/endemism*, such as Brukkaros, the Karas Mountains or the western escarpment, currently lack formal protection. There are already communal campsites in the Brukkaros/Berseba/Tses area – there is potential to develop these into a communal conservancy centered on the scenic and biodiverse Brukkaros Mountain. This is currently being done through the emerging Berseba Conservancy. The Karas Mountains have high scenic appeal and healthy game stocks, and there are already a number of guest farms operating in the area – there is potential to develop these into a commercial conservancy as well.

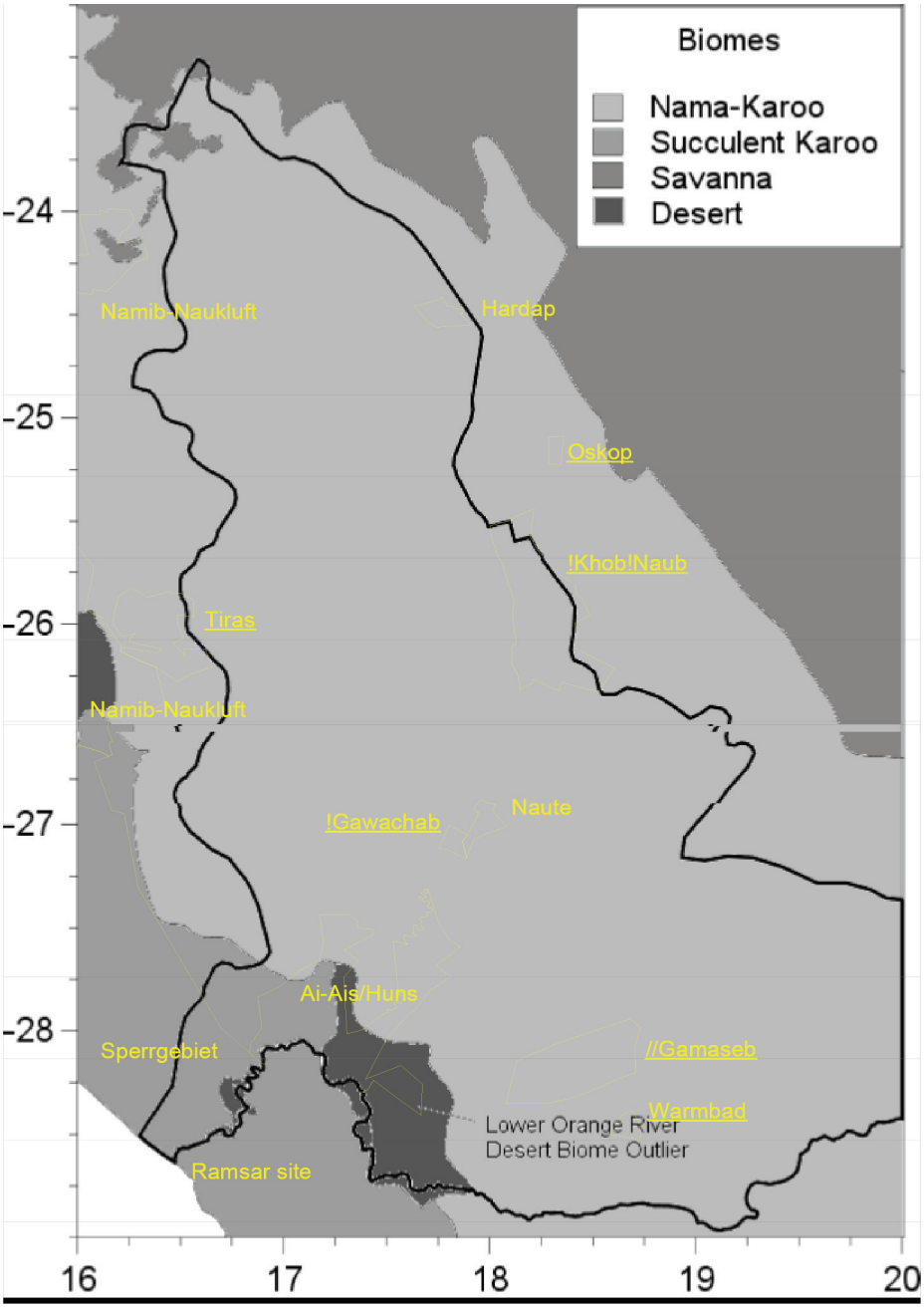


Figure 9: State and private (underlined) conservation areas in the OFRB, showing biome coverage.

6 Useful or otherwise important species

One known plant species with economic potential in the OFRB is *Hoodia gordonii*, and it is already being exploited. It is a matter of concern that at least five other *Hoodia* species occur in the OFRB, of which at least one is endemic (Bruyns 1993). Given the experience of individuals claiming ancestral rights to *Hoodia* but being unable to distinguish it from the alien *Opuntia*, there is some concern that *Hoodia* harvesters might inadvertently decimate non-target species.

The Asteraceae of the Succulent Karoo are responsible for a winter floral display that is an important component of the area's tourism appeal. The OFRB includes many rare succulents that are in high demand from collectors (e.g. *Lithops*). Indigenous nurseries are an untapped source of income for the OFRB, both directly through sales and indirectly through tourism interest, besides contributing to conservation by removing the reason for the existence of a black market in succulents.

Game is an important resource that is being utilised, for example, in trophy hunting. It also has tourism appeal that could be enhanced by re-introducing extinct species (see below).

Range-restricted endemic species, especially the more photogenic ones, could become value-added attractions for tourist establishments. Some possible candidates for niche tourism include:

- Brukkaros mongoose, *Galerella swalius*
- Mountain ground squirrel, *Xerus princeps*
- *Aloe argenticauda*, and succulents in general
- Nama padloper, *Hompus solus*
- Girdled lizards, *Cordylus* spp.

Unfortunately many endemics, including most invertebrates and plants, are not particularly spectacular.

At least 86 grasses occur in the OFRB (van Eck 2007), but most are not particularly good grazing:

- High grazing value: 14 species
- Average grazing value: 32 species
- Low grazing value: 40 species.

This confirms that the OFRB is marginal stock farming country at best, as already stated.

At least 40 species of toxic plants of veterinary importance are found in the OFRB (Mannheimer, Marais and Schubert 2007). Most also occur elsewhere in Namibia, but the following are largely specific to the OFRB:

- Bitterkambro, *Adenium oleifolium*
- Fire sickness bush, *Athanasia minuta*
- Kinkelbos, *Tetragonia schenckii*
- Kandelaarsbos, *Tylecodon wallichii*.

7 Alien species

A map of the number of alien species recorded per QDS from the OFRB (Figure 10) shows suspiciously high numbers of aliens in the better-sampled localities mentioned above (Naukluft, Keetmanshoop, Mariental). The two QDSs with the highest number of aliens recorded are both along the Orange River and both relatively well-sampled (Figure 5).

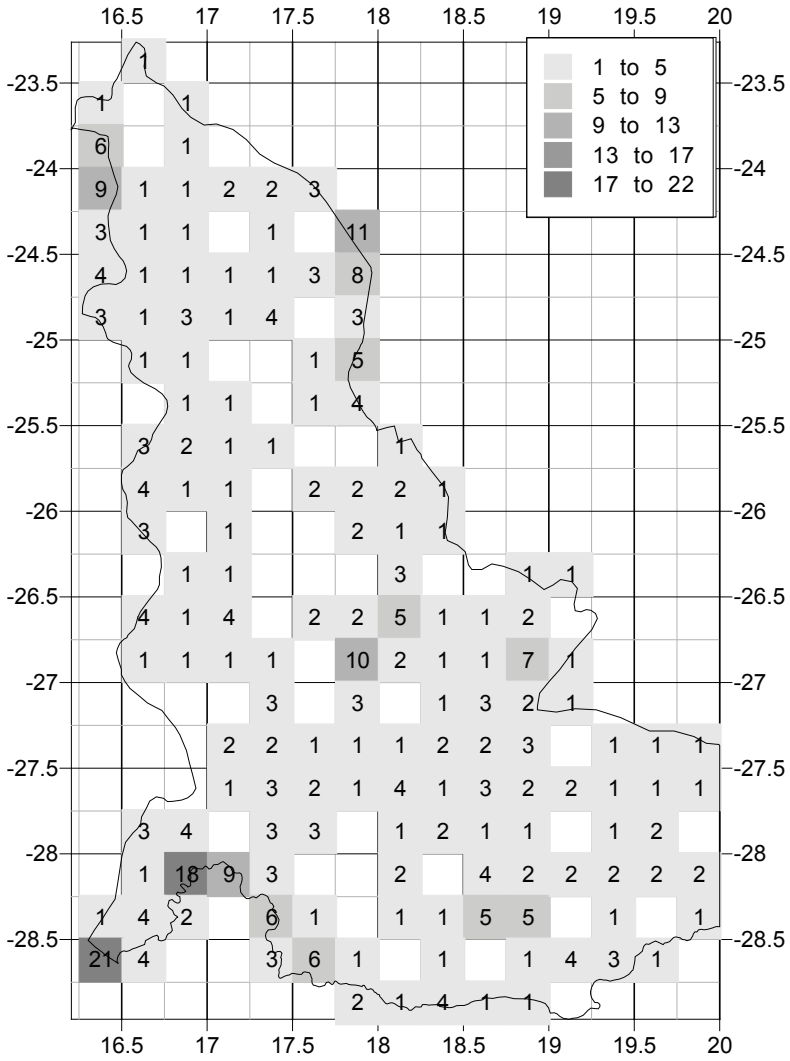


Figure 10: Number of alien species recorded per QDS in the OFRB.

The aliens recorded from these two QDSs include three birds:

- House sparrow, *Passer domesticus*
- Feral pigeon, *Columba livea*
- European starling, *Sturnus vulgaris*,

and 29 plants, of which the commoner species are:

- Wild tobacco, *Nicotiana glauca*
- Honey mesquite, *Prosopis glandulosa*
- Castor oil plant, *Ricinus communis*
- Couch grass, *Cynodon dactylon*
- Port Jackson willow, *Acacia saligna*
- Mexican poppy, *Argemone ochroleuca*
- Red water fern, *Azolla filiculoides*.

The birds are almost exclusively associated with human habitation, and the plants are largely confined to the immediate vicinity of the Orange River. The alien plants pose the usual threat of displacing the indigenous riverbank vegetation and rendering the habitat unsuitable for indigenous species. Given that the Lower Orange River has a very narrow strip of riverbank vegetation only, and that this vegetation acts as a linear oasis and dispersal route for biota that cannot survive away from the river, this is a matter of some concern.

8 Historical mammal incidence and possible re-introduction

A number of mammal species are known to have suffered range reduction or regional extinction within the OFRB as a result of human influence in historical times. No birds, reptiles or other taxa are known to have become extinct in the OFRB. Those mammals that are potential candidates for re-introduction because of tourist potential or ecosystem function, are discussed below. (Species sequence as in Appendix 1.)

8.1 Dik-dik – *Madoqua kirkii*

Dik-dik are commonly encountered in northern Namibia, but not in the south. However, there are old records from Brukkaros (Griffin and Coetzee 2006) and near the Karas Mountains and Fish River Canyon (Joubert and Mostert 1975). The evidence for their occurrence in these latter areas is slim, but given proper research, re-introduction to places with sufficient cover to support these shy animals might be appropriate.

8.2 Grey rhebuck – *Pelea capreolus*

The case of the grey rhebuck is listed here as an example. Historically, there was a number of more or less vague and unsubstantiated records from southern Namibia, e.g. Drews (1910), or Shortridge (as quoted in Skead, 1980). By the second half of the 20th Century, the consensus opinion was that grey rhebuck had never occurred in Namibia. In 1992, photographic evidence was provided, and they are now known to occur in both the Schakalsberge and the Huns Mountains (Griffin and Coetzee 2006). They are probably at the ecological limits of grey rhebuck occurrence at these places already and their re-introduction elsewhere, even if also within the Succulent Karoo, is not recommended.

8.3 Red hartebeest – *Alcelaphus buselaphus*

Red hartebeest today are mainly found in the sandy Kalahari areas to the east of the OFRB, but there are historical records from the northern OFRB (Gibeon, Maltahöhe and Rehoboth areas) (Joubert and Mostert 1975, Skead 1980). Most of the Nama-Karoo would probably not be suitable habitat for them, but they may be potential candidates for re-introduction in the Nama-Karoo/Savanna ecozone in the northern OFRB.

8.4 Buffalo – *Syncerus caffer*

Buffalo used to be common in the OFRB, apparently concentrated along the Fish River and its major tributaries (Skead 1980). In contrast to most other mammals that have disappeared from the OFRB, they were not hunted out, but were completely decimated by the rinderpest of 1896 (Shortridge 1934). As grazers, they would probably need extensive foraging ranges to survive in the less than optimal OFRB. With that constraint, they could be candidates for re-introduction.

8.5 Black wildebeest – *Connochaetus gnou*

8.6 Blesbok – *Damaliscus dorcas*

There is no evidence to suggest that either of these two species (black wildebeest and blesbok) ever occurred in Namibia, but their ready availability at game auctions in South Africa has resulted in them having been imported to Namibia in the past (Griffin and Coetzee 2006). Since both could thrive in many Nama-Karoo parts of the OFRB, they are mentioned here specifically as species that ***should not be introduced***.

8.7 Hippopotamus – *Hippopotamus amphibius*

The former existence of hippo in the Lower Orange River and their extermination by the 1920s is well documented (Skead 1980). There are no records of hippo from the Fish River, but this is to be expected – the limited amount of grazing next to the Lower Orange probably placed it at the limits of potential hippo habitat, and there would have been even less along the Fish River. Given the already marginal habitat, the impossibility of containing hippos, their propensity to wander, and the many commercial crop farms along the Lower Orange, re-introduction of hippo would probably not be a good idea.

8.8 Giraffe – *Giraffa camelopardalis*

Giraffe were common throughout the Nama-Karoo parts of southern Namibia in historical times (Skead 1980). They are prime candidates for re-introduction where there is suitable habitat (extensive *Acacia erioloba* parkland along major watercourses). Giraffes were recently re-introduced to the Gondwana Park.

8.9 Warthog – *Phacochoerus africanus/aethiopicus*

The warthog of central and northern Namibia, and most of the rest of Africa, is *P. africanus*. It was recently shown that *P. aethiopicus*, formerly treated as a synonym for *P. africanus*, is a distinct species that survives in Somalia. It also occurred in south-western Africa until about 1860, but is now believed to be extinct in southern Africa (Grubb 1993). There are several other mammal species or superspecies with Afro-arid disjunct distributions between north-eastern and south-western Africa (dik-dik, oryx, steenbok, black-backed jackal, bat-eared fox, springhare, etc.). There are very few southern African *P. africanus* specimens known, and even fewer with proper localities, but based on what little is known, as well as their habitat in Somalia, they were probably Nama-Karoo animals.

There is thus a possibility that they may have occurred in southern Namibia as well, but Skead (1980) could trace no records of any warthog from there. The latest Namibian mammal checklist (Griffin and Coetzee 2006) recognises *P. africanus* only, and lists it as not occurring in southern Namibia. However, an earlier study by Joubert and Mostert (1975) mapped warthog at a few scattered localities in southern Namibia based on questionnaire results.

This raises the tantalising possibility that some of these vague warthog records from the south might refer to surviving pockets of the presumed extinct Cape warthog (refer to the grey rhebuck case above). An investigation of the dentition of OFRB animals would be diagnostic. The case is certainly worth further investigation and until it is resolved, no warthog from northern Namibia or anywhere else should be re-introduced to the OFRB, in order to avoid genetic contamination of resident populations.

8.10 African clawless otter – *Aonyx capensis*

8.11 Spotted-necked otter – *Lutra maculicollis*

Shortridge (1934) recorded both otter species from the Orange River, and mentioned ‘otters’ as ranging up the Fish River as far as near Berseba. The latter may have been based on hearsay, as no specimens apparently exist to substantiate this claim (given that Shortridge’s main collections and information on them remains largely inaccessible to Namibians to this day). However, it definitely seems possible on ecological grounds. Certainly the Fish River formerly had enough water and fish to support otters. There are

no recent records of either from the Fish River, and none of the spotted-necked otter from the Orange River either (Griffin and Coetzee 2006).

The case of the spotted-necked otter in the Orange needs more study to determine whether it has become extinct, or never occurred there in the first place – in the latter case it would obviously not be a candidate for introduction, in the former case, the reasons for extinction would need to be evaluated. The clawless otter may be a candidate for introduction if suitable habitat can be found along the Fish River, as long as there is no possibility for conflict with e.g. local communities' chickens. Otters also have high tourism appeal.

8.12 Wild dogs – *Lycaon pictus*

Wild dogs were occasionally recorded throughout the OFRB until the mid 20th Century (Hines 1990). Today they do not occur there any more, are only found in far north-eastern Namibia, and the species has a global IUCN status of 'Endangered' (Griffin and Coetzee 2006). Given that the OFRB is climatically not prime wild dog habitat, that they need lots of space and game stocks to support them and that there is a high potential for conflict with stock farmers, the introduction of wild dogs is not recommended. Efforts to save the species would be better directed to more suitable areas.

8.13 Lion – *Panthera leo*

Skead (1980) lists a number of historical records of lion from throughout the OFRB, where they appear to have been very common in the past. Lions have tremendous tourism potential, but also need large game populations to support them, and have a high potential for conflict with stock farmers. Their re-introduction into the OFRB is not recommended.

8.14 Black rhinoceros – *Diceros bicornis*

Skead (1980) lists numerous sources for the previous existence of black rhino in the Nama-Karoo part of the OFRB. Many parts of the Nama-Karoo resemble those parts of western Damaraland in character, substrate and vegetation, where rhino still occur. Rhino are prime candidates for re-introduction, provided they can be adequately contained and protected. They have very high tourism potential and low potential for conflict with neighbours.

8.15 White rhinoceros – *Ceratotherium simum*

Skead (1980) lists a number of references to white rhino in southern Namibia. For most of the 19th Century, as many as four different African rhino species were recognised, distinguished primarily by horn shape and length (e.g. Andersson 1856: 386). Today we know that horn configuration is a non-character, therefore little credibility can be given to historical records unaccompanied by specimens or illustrations. On ecological grounds, the grazing white rhino is less likely to have occurred in the OFRB, and most records probably refer to the browsing black rhino instead. In the absence of concrete evidence for their former existence, as well as general ecological unsuitability, re-introduction of the white rhino into the OFRB is not recommended.

8.16 Mountain zebra – *Equus zebra*

Today there is a large gap in distribution between mountain zebra populations in the Huns Mountains/Fish River Canyon area, and the Zaris Mountains west of Maltahöhe (Joubert 1973). Although Shortridge (1934) mapped their occurrence along the escarpment as continuous, there are no definite historical records from this gap. The terminological confusion between 'zebra', 'quagga' and 'wild horse' renders many

historical records unusable (Skead 1980), but on ecological grounds one may expect that mountain zebra used to occur all along the southern Namibian escarpment. Their re-introduction into suitable areas here might be appropriate.

8.17 Vervet monkey – *Chlorocebus pygerethrus*

Vervet monkeys are common along the Orange River. Shortridge (1934) mentioned them as ranging up the Fish River as far as near Berseba, but, as is the case for otters, this might also have been based on hearsay, as no specimens to substantiate it survive. There are no recent records from the Fish River (Griffin and Coetzee 2006). Re-introduction of vervet monkeys into the OFRB is not recommended. Experience in other conservation areas shows that they tend to squat and become a nuisance when presented with the scavenging opportunities around human habitation. Their potential problem status negates any potential tourism appeal.

8.18 Elephant - *Loxodonta africana*

Skead (1980) lists only a few oblique references to elephant in southern Namibia. On ecological grounds, there is no reason why small highly mobile populations similar to those surviving in western Kaokoland could not have occurred throughout the Nama-Karoo part of the OFRB, particularly along the Orange and Fish Rivers themselves. Elephants have high tourism potential, but are a management nightmare – they need lots of space, do not respond to fencing, and can be destructive to infrastructure. Their re-introduction into the OFRB is not recommended.

9 Summary

The OFRB is biogeographically diverse and represents all four biomes of Namibia. Despite almost 3,000 species being known from there, biodiversity knowledge of the OFRB as reflected in the datasets used here is too unevenly spread to conclusively identify biodiversity and endemism hotspots. However, some candidates do emerge. They are the western escarpment, including the Naukluft area and the Rosh Pinah/Obib area; the Huns/Fish River Canyon area; the Karas Mountains; Brukkaros Mountain and the Warmbad area. Some parts of the OFRB are particularly undersampled and could benefit from further sampling/inventorying.

For much of the OFRB, eco-tourism represents the most viable, sustainable and profitable land-use. Several useful or important species of plants or animals could be developed to enhance tourism potential, including the re-introduction of historically extinct species. The status of the presumed extinct ‘Cape warthog’ may merit further investigation.

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